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Taxonomy and distribution of a tropical weed: *Chromolaena odorata* (L.) R. King & H. Robinson

LAURENT GAUTIER

ABSTRACT

GAUTIER, L. (1992). Taxonomy and distribution of a tropical weed: *Chromolaena odorata* (L.) R. King & H. Robinson. *Candollea* 47: 645-662. In English, English and French abstracts.

The first part of this article considers the nomenclature and classification of a major tropical weed: *Chromolaena odorata*. The second part analyses the history of the distribution of the species. Originally restricted to the neotropics, it was introduced in India in the second part of the last century and from there, it spread to Asia and Oceania. It appeared in three different locations in Africa around the second World War, and is still spreading. The causes of the introductions are briefly discussed, and the responsibility of man as a deliberate introducer are brought to the fore. A potential distribution map is proposed, and the regions still under threat are pointed out.

RÉSUMÉ

GAUTIER, L. (1992). Taxonomie et distribution d'une adventice tropicale: *Chromolaena odorata* (L.) R. King & H. Robinson. *Candollea* 47: 645-662. En anglais, résumés français et anglais.

La première partie de cet article est consacré à la nomenclature et à la classification d'une importante espèce adventice tropicale: *Chromolaena odorata*. L'auteur présente ensuite l'histoire de la distribution de l'espèce. Originnaire d'Amérique tropicale, elle a été introduite en Inde pendant la deuxième moitié du siècle passé. De là, elle s'est répandue en Asie et en Océanie. Elle est ensuite apparue en trois différents endroits d'Afrique aux alentours de la seconde guerre mondiale. Elle y continue son expansion. Une brève analyse des causes des introductions est donnée. Elle met en évidence la responsabilité de l'homme, qui a souvent été à l'origine d'introductions délibérées. Une carte de l'aire de distribution potentielle de l'espèce est proposée, et les régions encore susceptibles d'être envahies sont énumérées.

Introduction

Chromolaena odorata (L.) R. King & H. Robinson (= *Eupatorium odoratum* L.) is a very important neotropical weed of the family *Asteraceae*, which has considerably extended its distribution to the paleotropics in the last 150 years. It has a bushy habit and forms a very dense thicket 2 m high, in almost pure stands. It is heliophilous and has a quick growing rate, due to a judicious allocation of resources. It is very invasive because of its massive production of small wind-dispersed seeds, that can also be dispersed on long-distance through exo-zoochory, clinging to furs, feathers or clothes.

Working in Ivory Coast, West Africa, where *Chromolaena odorata* first appeared around 1950, I met it in all types of secondary vegetation in the southern half of the country. It occupies clearings

in the forest zone and often invades plantations. It can also develop in the savannas of the forest-savanna transition zone located in the center of the country, if they aren't burned regularly.

This is an introductory article of a series dealing with the ecological implications of this introduction, extracted from a doctoral thesis (GAUTIER, 1992). It is dedicated to the taxonomy and nomenclature of the species, as well as its distribution on a world-wide scale.

Taxonomy

To our knowledge, the species was first mentioned in scientific literature in the book *Phytographia* by PLUKENET (1692). The plant is illustrated by an etching, with the polynomial denomination "Eupatoria Conyzoides folio molli & incano, capitulis magnis, Americana", together with a geographical indication "Barbadiensibus dicta" and its local name "Arch-angel", which is still in use in the English-speaking West Indies.

It is then met in the book that BROWNE (1756) dedicates to Jamaica, also under a non-linnean appellation: "Eupatorium Odoratum hirsutum; foliis ovato-acuminatis, basim versus crenatis, oppositis; floribus comosis". The author refers to the book of Plukenet and quotes the same local name. He also gives brief descriptions of its habitat, habit and scent.

The first botanist to give a binomial name to the species is Linnaeus in May-June 1759 (LINNAEUS, 1759a, p. 1205), studying plants that Browne brought back from Jamaica. The chosen name was *Eupatorium odoratum*. A short diagnosis is given, with a reference to Plukenet.

In November of the same year, in the text of a thesis concerning Jamaican plants, he adds a more precise description. (LINNAEUS, 1759b, p.22).

Generic classification

Drawing attention to the generic classification of this species brings into question the whole taxonomy of the tribe *Eupatorieae*.

The genus *Eupatorium*, dedicated by Tournefort to Mithridate Eupator, had been used by Linnaeus in 1753, who described amongst others *Eupatorium cannabinum*, which will be chosen later as lectotype of the genus.

It is obvious that this species is related to *Eupatorium cannabinum*, but at what precise level? According to Linnaeus, it should be at the generic level. Nevertheless, when one considers the tremendous numbers of species described in this genus in the last century, it soon appeared necessary to split it in taxonomically distinct units.

Cassini, to which the definition of the tribe *Eupatorieae* can be attributed, writes already in 1826 in his contribution to the *Dictionnaire des Sciences naturelles* by Cuvier (43: 262): "Le genre *Eupatorium* est tellement nombreux en espèces, que, loin de chercher à étendre ses limites, on doit, selon nous, tâcher de les restreindre autant qu'il est possible". Following this point of view, new genera were described among the tribe *Eupatorieae* in the nineteenth century.

DE CANDOLLE (1836), for instance, added new genera to the tribe. Concerning the genus *Eupatorium*, he split it in series and sections. Our species is included among the first series *Imbricata*, in the first section *Cylindrocephala*.

The first step towards the splitting at the generic level was later taken by SCHULTZ-BIPONTINUS (1866). In his treatment, the genus *Eupatorium* in a broad sense is split according to the shape of the fruits. He transferred some species to the genus *Praxelis* Cass., and created the new genus *Osmia*, which is typified by *Osmia odorata* (L.) Sch.-Bip., which is nothing other than *Eupatorium odoratum* L.

In the beginning of the 20th century, this treatment met little success among botanists who still use the broad genus *Eupatorium*, partially for practical reasons, being easy to identify. Nevertheless, for non-specialists, the determination at the species level is very troublesome, because of the great number of species involved.

It should be stressed that the tribe is nowadays estimated to have around 2000 species, that is 10% of the family *Asteraceae*, or 1/150 of the flowering plants (KING & ROBINSON, 1987), and that the great majority is traditionally placed in the genus *Eupatorium* s.l.

For instance, according to BENTHAM (1873), the tribe is made of 800 species in 35 genera, with 460 species in the genus *Eupatorium*. According to HOFFMAN (1894), there are 900 species in 42 genera, with 400 species in the genus *Eupatorium*. Finally, with B. L. ROBINSON (1913), the number of genera reaches 48.

A global revision of the tribe was thus necessary. This tremendous work has been undertaken by R. M. King and H. Robinson in the 1960's, and is still going on. The major part of the work is nevertheless behind, and is being published in an impressive number of papers. Fortunately, the authors have recently summarized their work in a recent monograph, adding a key to separate the genera (KING & ROBINSON, 1987). In addition to the classical characters, the authors base their work on microscopic and cytologic studies, as well as chemical analyses and phytogeographical considerations.

According to them, the tribe should be separated in 18 subtribes and 180 genera. The genus *Eupatorium* is thus restricted to 45 species of arcto-tertiary distribution, mostly concentrated in North America. A few taxa are met in Asia, to which they probably proceeded through the Bering Strait, the only species to reach Europe being the type-species: *Eupatorium cannabinum*.

Following KING & ROBINSON (1970), our species is included in the genus *Chromolaena* DC., Prodr. 5:133 (1836) created by De Candolle to include a single species: *Chromolaena horminoides* DC.

This genus now includes the section *Cylindrocephala* of De Candolle, the genus *Osmia* of Schultz-Bipontinus, and of course the homonymous sections of Baker in the Flora of Brazil edited by Martius, bringing the number of species in the genus to 165.

The name of our species thus becomes:

***Chromolaena odorata* (L.) R. King & H. Robinson in Phytologia 20: 204 (1970).**

Since I am not a specialist in the taxonomy of the *Asteraceae*, it is not my duty to cast any judgement on the worthiness of this treatment. It is often heard that if a splitting of the genus *Eupatorium* was highly desirable, King & Robinson went maybe a little too far, especially in the great number of genera they consider in the tribe. The authors defended themselves (ROBINSON & KING, 1985) arguing that the complexity of the treatment only reflects the complexity of the tribe. They conclude that: "The extent to which some botanists resist the changes in the classification of the tribe *Eupatorieae* is the extent to which they do not know its phylogeny."

From another point of view, it is obvious that a revision of this size will meet all kinds of more or less grounded objections. A botanist is always annoyed to see a species changing its name, and in this case it is more than a thousand species that are concerned. It is also important to realize the amount of work necessary to reclassify the whole tribe in herbaria of a certain importance. In this respect, it is significant to state that the institutions which have first adopted these changes are generally smaller medium-sized herbaria, located in the Old World, far from the diversification center of the tribe, where the changes only concern a fistful of local species and a few pantropical weeds.

Among the applied scientists who work in fields such as weed science, pedology, agronomy, the name *Chromolaena odorata* spread rather quickly. That's partly why I decided to use it. On the other hand, when I consider the collections that I had the opportunity to handle in the herbarium in Geneva, it is my opinion that the genus *Chromolaena* as delimited by King & Robinson is rather homogenous and distinct. Nevertheless, from a macroscopic point of view, it seems that the number of species it includes could be diminished by some judicious reduction in synonymy, particularly around *Chromolaena odorata*.

Synonymy

According to the recent conceptions of King & Robinson, synonymy of the species could be established as follows:

- Chromolaena odorata** (L.) R. King & H. Robinson in *Phytologia* 20: 204 (1970).
 ≡ *Eupatorium odoratum* L., *Syst. Nat.* ed. 10: 1205 (1759).
 ≡ *Osmia odorata* (L.) Schultz-Bip. in *Pollichia* 22-24: 252 (1866).
 = *Eupatorium conyzoides* M. Vahl, *Symb. Bot.* 3: 96 (1794) [non Miller, *Gard. Dict.* ed 8: *Eupatorium* n°14 (1768)].
 ≡ *Osmia conyzoides* (Vahl) Sch.-Bip. in *Pollichia* 22-24: 252 (1866) [nom. illeg.].
 = *Eupatorium floribundum* Kunth in Humboldt & al., *Nov. Gen. Sp.* 4, ed. folio: 92 (1818).
 ≡ *Osmia floribunda* (Kunth) Schultz-Bip. in *Pollichia* 22-24: 252 (1866).
 = *Eupatorium brachiatum* Wikström in *Kongl. Vetensk. Acad. Handl.* 1827: 71 (1827).
 = *Eupatorium divergens* Less. in *Linnaea* 5: 138 (1830).
 ≡ *Osmia divergens* (Less.) Schultz-Bip. in *Pollichia* 22-24: 252 (1866).
 = *Eupatorium affine* Hook. & Arn. in *Companion Bot. Mag.* 1: 240 (1835).
 = *Eupatorium clematitis* DC., *Prodr.* 5: 144 (1836).
 = *Eupatorium graciliflorum* DC., *Prodr.* 5: 145 (1836).
 ≡ *Osmia graciliflora* (DC.) Sch.-Bip. in *Pollichia* 22-24: 252.
 = *Eupatorium stigmatosum* Meyen & Walp. in *Nov. Actorum Acad. Caes. Leop.-Carol.* *Nat. Cur.* 19, *Suppl.* 1: 257 (1843).
 = *Eupatorium sabeanum* Buckley in *Proc. Acad. Nat. Sci. Philadelphia* 1861: 456 (1861).

It should be noted that the name *Eupatorium conyzoides* Vahl, *Symb. bot.* 3: 96 (1794), which was currently used in the last century is illegitimate, having been used before by Miller, *Gard. dict.* ed. 8: 14 (1768). Referring to Sloane *Cat. Jam.* 124, Miller described under this name a species which can not be surely bound to ours. In the first edition of *Index Kewensis*, as well as in the recent monograph of KING & ROBINSON (1987), it is considered as a synonym of *Vernonia arborescens* (L.) Sw., while for B.L. ROBINSON (1918), it is a synonym of *Eupatorium odoratum* (L.).

In the first edition of *Index Kewensis*, numerous names are considered as synonyms of *Eupatorium conyzoides* Vahl non Mill. Some are still considered as synonyms of *Chromolaena odorata* by King & Robinson, whereas some others have been treated as distinct species:

- Eupatorium ciliatum* Less. in *Linnaea* 6: 404 (1831).
 ≡ *Ageratina ciliata* (Less.) R. King & H. Robinson
- Eupatorium maximiliani* DC., *Prodr.* 5: 143 (1836).
 ≡ *Chromolaena maximiliani* (DC.) R. King & H. Robinson
- Eupatorium mucronatum* Gardener in *London J. Bot.* 6: 440 (1847).
 ≡ *Chromolaena mucronata* (Gardener) R. King & H. Robinson
- Eupatorium hookerianum* Griseb. in *Abh. Königl. Ges. Wiss. Göttingen.* 19: 166 (1874).
 ≡ *Chromolaena hookeriana* (Griseb.) R. King & H. Robinson

A name couldn't be placed with certainty by King & Robinson:

- Chrysocoma maculata* Vell., *Florae Fluminensis*: 325 (1829).
 ≡ *Chromolaena hookeriana* (Griseb.) R. King & H. Robinson
 or = *Chromolaena odorata* (L.) R. King & H. Robinson

Geographic distribution

History of the distribution and present state

In order to know the present distribution of *Chromolaena odorata* and to try to predict what regions could still be invaded, I have studied the history of its distribution from literature on one hand and from herbaria collections on the other hand.

The following herbaria have been visited (acronyms according to HOLMGREN & al., 1990):

- Ivory Coast, Centre National de Floristique (UCJ)
- Ivory Coast, O.R.S.T.O.M. Adiopodoumé (ABI)
- Genève (G)
- Hamburg (HBG)
- I.E.M.V.T., Maisons-Alfort, Paris (ALF)
- Kew (K)
- Paris (P)

In addition, an inquiry form was sent to some of the major herbaria in the world, and to all African herbaria, asking for a census of the specimen of the species that were present in their collections. It was encouraging to note that most of the herbaria answered to this request, either by a loan, or by filling the inquiry form, which, according to the size and location of the herbarium, must have been time-consuming. I would like to take this opportunity to thank all the persons involved.

It should be pointed out that I couldn't ascertain the determinations of the specimen that were not sent on loan.

The following herbaria were able to give information about all their specimen of *Chromolaena odorata*:

ACD; BENIN; BOL; CTES; DSM; EA; ESN; ETH; F; GC; GRA; IEC; IFE; J; KHF; L; MAL; NAI; NBG; NDO; NH; NU; PEU; PRE; ROML; SI; SRGH; STE; TFD; TOGO; U; UCI; UZL; WIND; WU; YA; YBI; Z.

The following herbaria, because of the size of their collections, could only give information about the specimen collected in the Old World:

B; BR; BM; C; E; M; NY; UC; US.

The inquiry form included the following questions:

- name of the collector
- number of the collection
- date of collection
- locality of the collection
- phenological state of the specimen

In that way, 1184 herbarium parts were censused, corresponding to almost 900 different collections. From there, 686 collections could be located, from which 639 with an accuracy of less than 1/4 degree and 47 approximately ($\pm 2^\circ$).

From the literature, I was able to add 157 points (97 precisely and 60 approximately).

The data were then classified according to their date of collection. For the information drawn from literature, the year of publication was used if no date of collection was mentioned.

The localities were then placed on maps, taking into account only the specimen collected until a certain date (Fig. 1 to 8). On these maps, localities issued from herbarium collections are represented by a circle, and those extracted from the literature by a triangle. The symbols are small and filled if the locality is precise, and large and hollow if the locality is approximate. For the maps of the Palearctic (Fig. 3 to 8), the year of the first apparition of the species in a country or an island, important because of its size or its isolation, was placed beside the corresponding symbol.

Neotropics (Fig. 1 and 2)

When one compares the two maps of the neotropics, it becomes obvious that the distribution of *Chromolaena odorata* hasn't changed since the end of the last century. But the density of localities is greater in the second map. It is unquestionable that *Chromolaena odorata* is here in its continent of origin, and that its distribution had reached its maximum range long before botanists started to collect. The increasing impact of man on environment could only create new sites for the plant in a region where it already existed when considered on a broader scale.

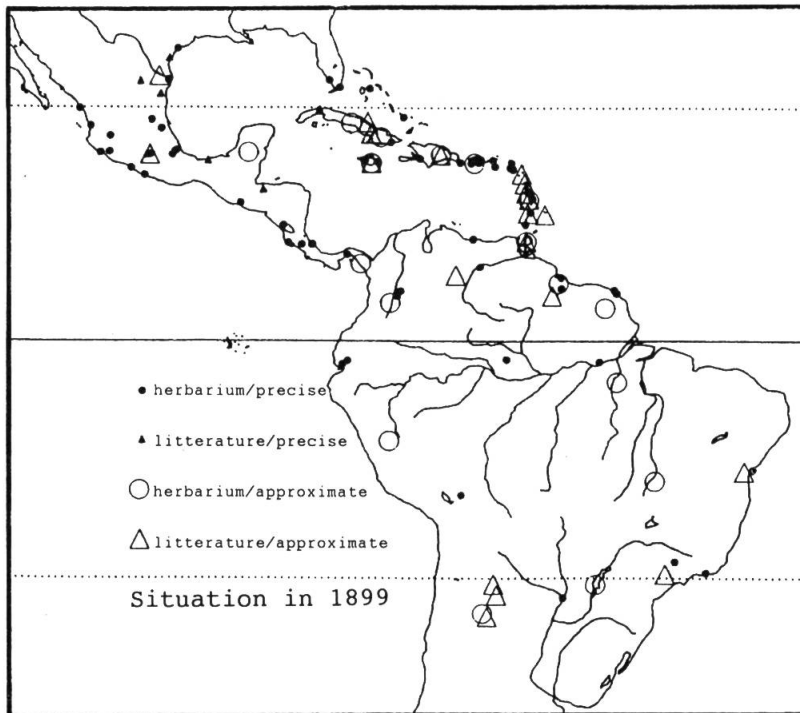
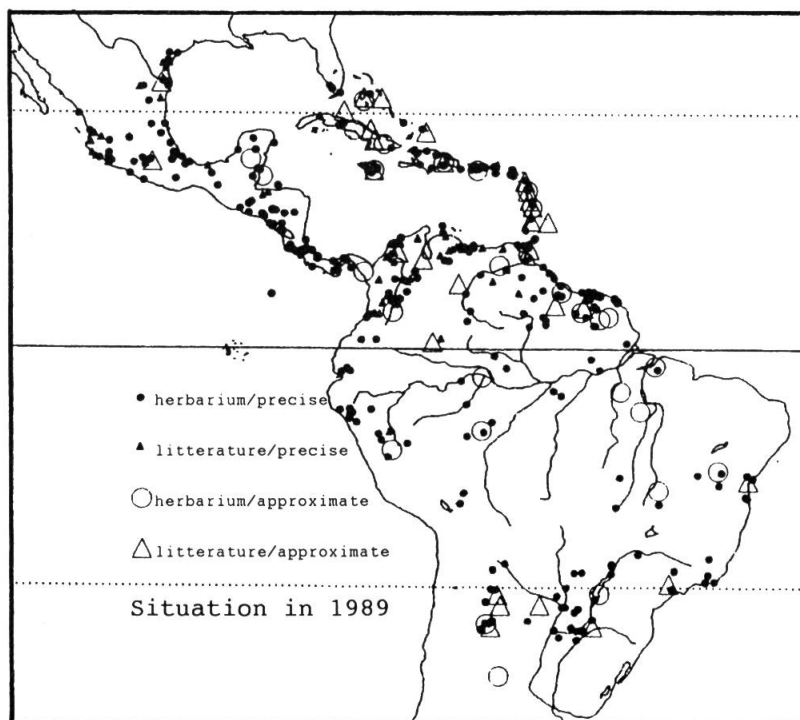


Fig. 1. — Distribution of *Chromolaena odorata* in the New World, according to data prior to 1900.

Fig. 2. — Distribution of *Chromolaena odorata* in the New World, according to data prior to 1990.



The species is found in all the West Indies and the Bahamas archipelago. According to BRITTON (1918), it was recorded once from Bermuda by Lefroy and cited by Hemsley but has not been found there since. Having never seen any sample from this island, I decided not to take it into consideration.

On the mainland, *Chromolaena odorata* is found in the United States, in the south of Florida and also in Texas, near the coast of the Caribbean Sea, from Corpus Christi to the Mexican border. From there towards the south, it is found between the Sierra Madre Oriental and the coast. South of the Tropic of Cancer, its range extends westward to the Pacific coast. It is then found throughout Central America.

In South America, the species never occurs above an altitude of 2800 m, and its distribution area is separated by the Andes. On the west side, the range extends down to the latitude of Cajamarca, where the coast becomes much drier. On the east side, all the intertropical part of the continent is occupied, maybe with the exception of the dry areas in the North-East of Brazil. South of the Tropic of Capricorn, the range extends through the Gran Chaco in Argentina until the province of Cordoba, around 31°S.

Asia and Oceania (Fig. 3 to 6)

The first proof of the apparition of *Chromolaena odorata* in Asia, and for the Paleotropics as a whole is a collection of C.B. Clarke in 1872 in India. In his book *Compositae Indicae* (CLARKE, 1876), the plant is mentioned as cultivated and escaped in Dacca and Java. The history of the distribution of the species confirms this naturalization in India, but for Java the first collection would be made only in 1941. At that time, *Chromolaena odorata* could well have spread from India, through Burma, Thailand and Malaysia. It is thus reasonable to think that the escape of the species in Indonesia in the last century had aborted, if it ever took place. This opinion is also strengthened by the fact that in the Krakatoa archipelago, where the vegetation is regularly censused since the great eruption of the volcano at the end of the last century, the species wasn't found before 1979 (FLENLEY & RICHARDS, 1982).

In Sri Lanka, an old collection by Trimen in the year 1884 in the gardens of Peradenya is the only record until 1938, when the species started a massive invasion (DASSANAYAKE, 1980). Very probably, the same case occurred here as in Java. The species didn't manage to escape from the botanical garden in the last century.

According to the data in my possession, the spread of *Chromolaena odorata* in Asia can be summarized according to the following steps:

- 1872: India (C.B. Clarke N° 16733, E; BM)
- 1876: Bangladesh (CLARKE, 1876)
- 1904: Thailand (E. Lindhard, without N°, HBG; M et N°32, C)
- 1905: Burma (J.H. Lace N° 2869, E)
- 1930: Laos (A. Petelot N° 1773, NY; US)
- 1930: Vietnam (CHEVALIER, 1949)
- 1930: Yunan, China (WU, 1982)
- 1936: Sumatra (Loerzing N° 17192, L; K)
- 1938: Malayan peninsula (Spare N° 34471, K)
- 1938: Sri Lanka (Yeushiwa N° 717, K)
- 1941: Java (Bruggeman, without N°, K; L)
- 1949: Borneo (Samsudin N° A 154, K)
- 1956: Nepal (Stainton N° 14, BM)
- 1961: Cocos-Keeling islands (H. St John N° 26459, G)
- 1962: Bismark archipelago (Dissing N° 2713, C; K)
- 1962: Marianna islands (STONE, 1966)
- 1963: Cambodia (Guinet N° 145, P)
- 1963: Philippines (E.J. Reynoso N° 87773, L)
- 1977: Sikkim (HOLM & al., 1977)
- 1978: Hainan, China (K.S. Chow N° 78211, NY; E; K; BM)

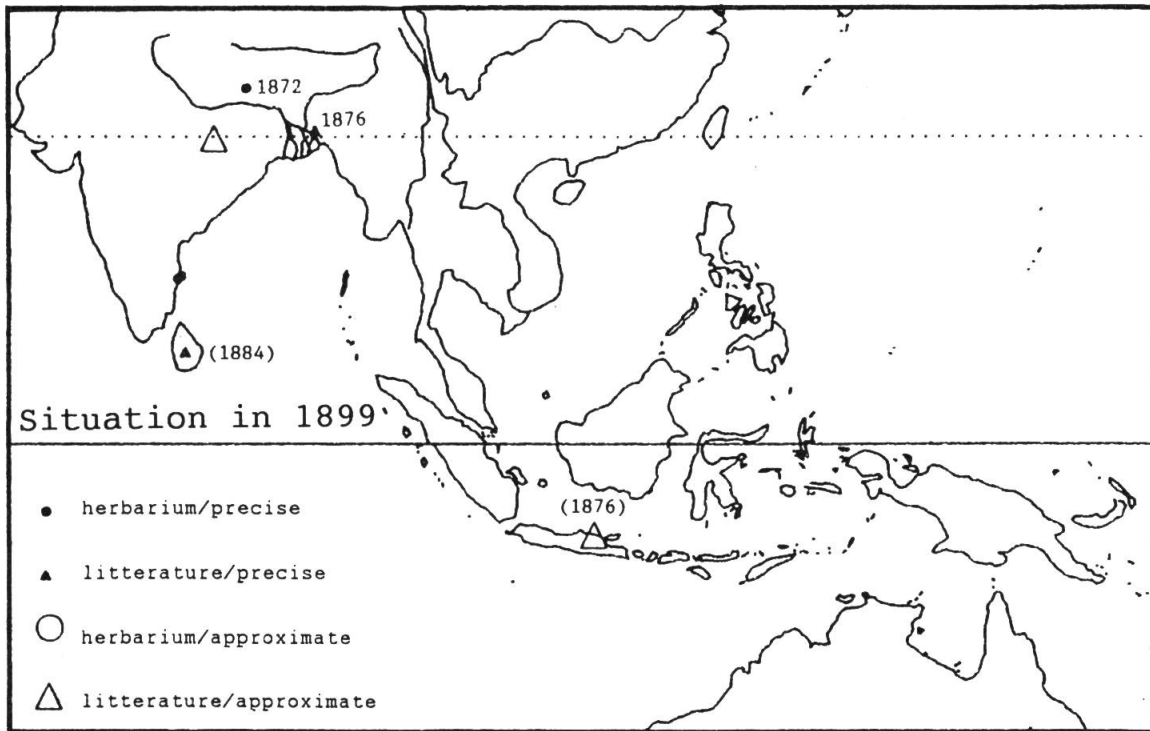
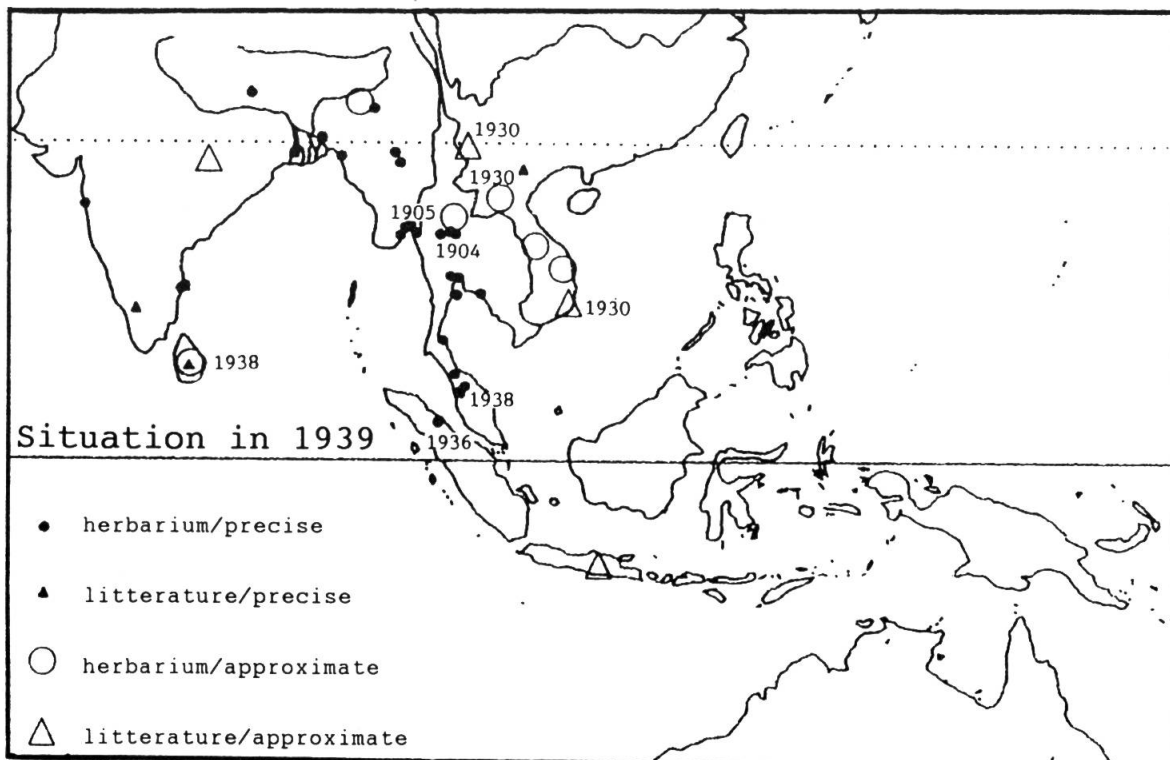


Fig. 3. — Distribution of *Chromolaena odorata* in Asia and Oceania, according to data prior to 1900.

Fig. 4. — Distribution of *Chromolaena odorata* in Asia and Oceania, according to data prior to 1940.



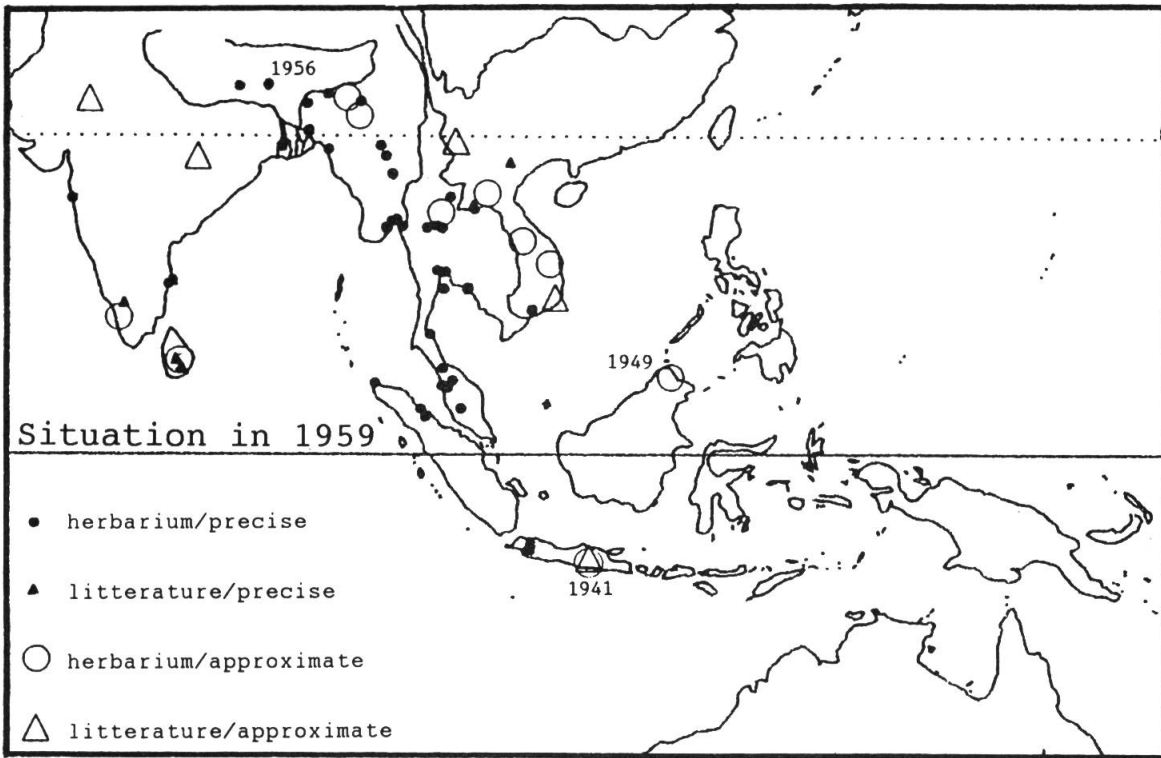
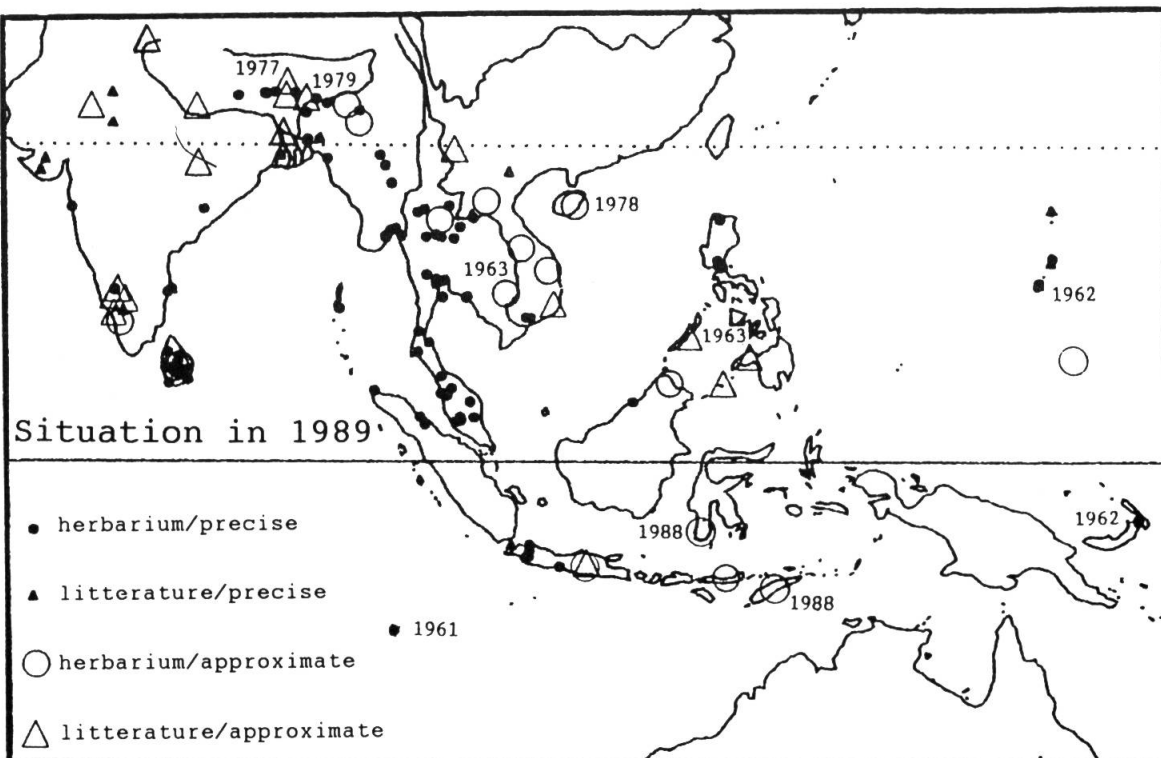


Fig. 5. — Distribution of *Chromolaena odorata* in Asia and Oceania, according to data prior to 1960.

Fig. 6. — Distribution of *Chromolaena odorata* in Asia and Oceania, according to data prior to 1990.



- 1979: Bhutan (Grierson & Long N° 711, E)
- 1988: Timor (CRUTWELL MACFAYDEN, 1989)
- 1988: Sulawesi (CRUTWELL MACFAYDEN, 1989)
- 1988: Carolina islands (CRUTWELL MACFAYDEN, 1989)

Thus, the species would have spread from a single locality in India. According to VAYSSIÈRE (1957), it would have been seen in Siam around 1880, and in Laos five years later. Without any precise citation or collection, these dates weren't taken into account for our maps, although they are most likely. For Cambodia, I lacked precise information and the first trace I could find is probably half a century later than its arrival.

The species would then have spread to the Malayan Peninsula in the thirties, or even before: 1918, according to an anonymous author cited by CRUTWELL MACFAYDEN (1989). It would then pass from one island to another in Indonesia, north-easterly to Marianna and Carolina islands, through Borneo and the Philippines, and easterly as far as Timor. The occurrence of the species in the Bismark Archipelago as early as thirty years ago could maybe be attributed to the north-easterly path, the plant being still unknown in New Guinea.

Africa (Fig. 7 and 8)

Unlike Asia, where the whole invasion of *Chromolaena odorata* probably initiated from one single site, it seems that in Africa the species established itself separately in different localities.

The first region to be reached was West Africa, where the plant spread from two different points. According to DELABARRE (1977), the introduction goes back to 1936-37, when pepper and coffee planters coming from South-East Asia settled in Cameroon and Central African Republic, bringing the species with them. During the same years, *Chromolaena odorata* would have appeared in Nigeria, contaminating seeds of *Gmelina arborea* Roxb. Ten years later, after the Second World War, the Asian planters would have moved to Ivory Coast, together with the weed.

According to my own data, the countries in West and Central Africa were colonized in this order:

- 1942: Nigeria (Jones N° 1040, BM)
- 1952: Ivory Coast (J. Miège, cited in DELABARRE (1977))
- 1961: Cameroon (Breteler & al. N° 2297, UC; M; P; K; BR; G; YA)
- 1963: Central African Republic (Bille N° 1420, ALF)
- 1965: Peop. Rep. of Congo (Sita N° 1183 IEC; P)
- 1969: Ghana (Hall & Enti N° GC 40207, K)
- 1970: Benin (J.A. Emiwogbon N° 61751, BEN)
- 1975: Zaïre (Pauwels N° 5389, BR)
- 1984: Togo (P.A. Schaefer N° 8010, TOGO)

These data confirm the hypothesis of a first introduction in Nigeria and of a separate introduction in Ivory Coast. Indeed, the three countries located between were invaded only later, the Ghana from the west and the Benin from the east. The two sources have certainly met now in Togo. West from Ivory Coast, our prospecting brought us to the borders of Guinea and Liberia where the species was still present. There is no doubt that it is spreading now in these two countries. As of information of January 1990, information indicates it had not reached the center part of Liberia (R. Paivinen, pers comm.).

On the contrary, the hypothesis of an introduction in the Cameroons and in the Central African Republic in the middle of the 30' doesn't find support in my data. On the contrary, everything happens as if these countries were colonized from the Nigerian source, from the West. Maybe my data is incomplete, weeds being not so often collected by botanists.

I have to take this opportunity to draw attention to the lack of recent data for Equatorial Guinea and Gabon. It is my opinion that *Chromolaena odorata* has certainly already spread to these countries. They have a suitable climate and are surrounded by severely infested countries like Cameroon and the Peoples Republic of Congo.

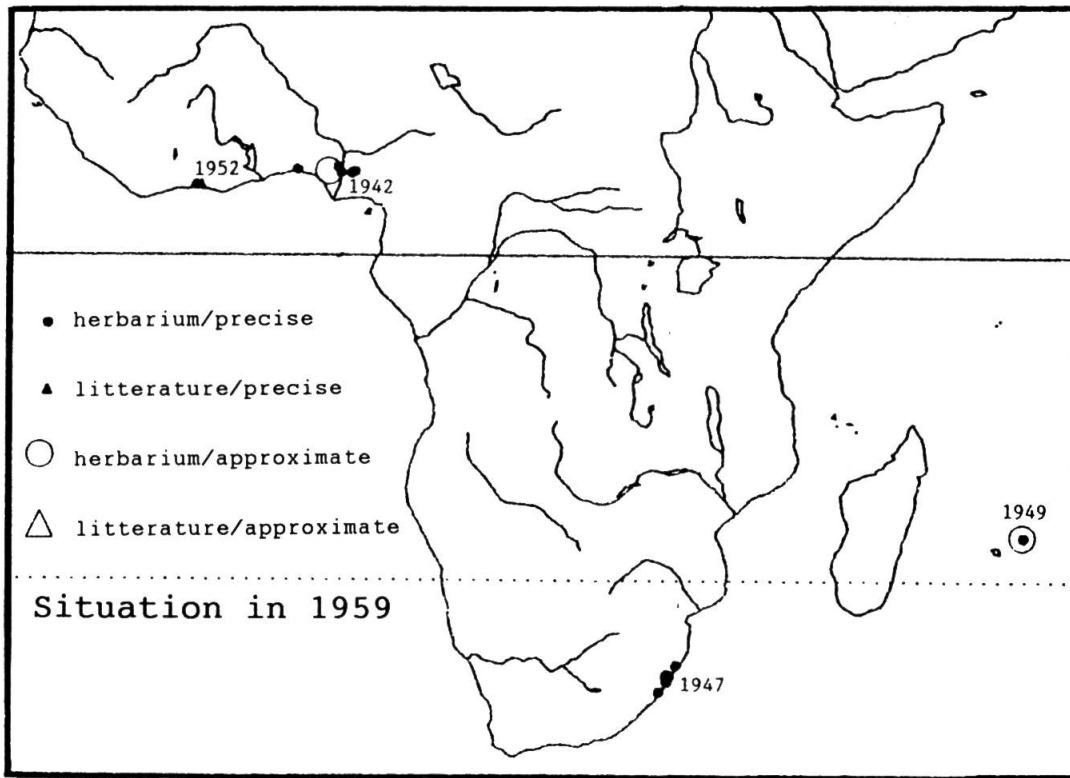
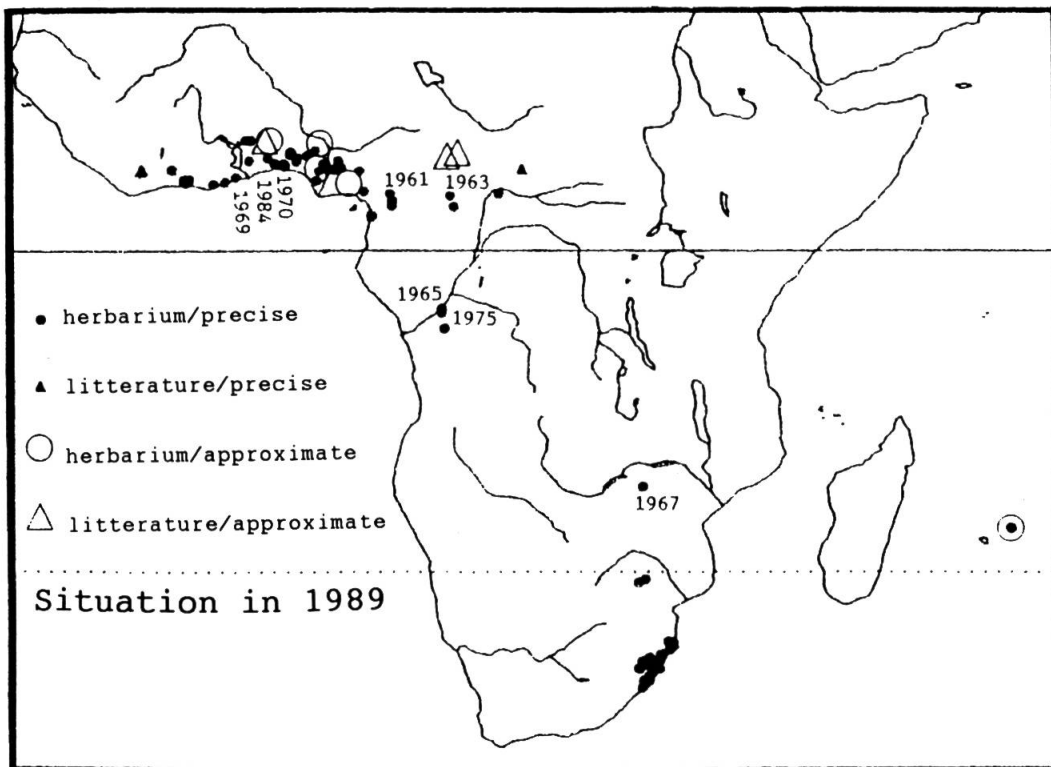


Fig. 7. — Distribution of *Chromolaena odorata* in Africa, according to data prior to 1960.

Fig. 8. — Distribution of *Chromolaena odorata* in Africa, according to data prior to 1990.



The spread should go on in central Africa eastward and southward, and will probably meet the third African source.

This third locality of introduction is located much more south, out of the tropical zone *sensu stricto*, in Natal, Republic of South Africa. The first collection goes back to 1947 (J. Ph. Acocks N° 13794, PRE), in the surroundings of Durban. From there, it spread along the warm and humid coast.

Southward, it reached the 31st parallel in 1976 (A. E. van Wyk N° 1679, PRE), and it appears to be not very far away from its ecological border.

Northwards, the species is found 150 Km away from its introduction site in 1950, and 280 Km away in 1961 (LIGGIT, 1983), around 28°S. According to this author, the plant has been found 40 Km further north since, and should continue its spread to Transvaal and Mozambique. In fact, two specimens have already been collected north of the Drakensberg in Transvaal, in 1980 (K. Cilliers without number, PRE) and in 1984 (I.A.W. Macdonald N° 37, PRE).

I still have to mention a collection made much further north, as early as 1967 in northern Zimbabwe (Baretta without number, U). With the lack of any other collection close in space or time, it is difficult to say anything on the origin of this colony. Nevertheless, I guess that the population probably grew from a long-distance anthropochorous dispersal from the south source.

Chromolaena odorata is also present in Mauritius where the oldest collection to my knowledge goes back to 1949 (Vaughan N° 3397, BM).

I have to make a few remarks on the distribution map published in HOLM & al. (1977). The plant is reported from Australia, probably referring to AULD (1977), and also in Senegal.

As far as Australia is concerned, it has been proved since that the species has not reached that country yet. The herbarium sheet on which this assumption was grounded is without data nor locality and was very probably collected by Cunningham during his trip to Brazil between 1814 and 1816. It was then incorporated in the herbarium in Melbourne in the general collections (CRUTWELL MACFAYDEN, 1989).

Concerning its presence in Senegal, I could find no reference other than the publication mentioned above, and no herbarium collection has ever reached me. Although the species could probably develop itself there, particularly in Casamance, I had to reject this locality.

It has long been thought that *Chromolaena odorata* was present in Hawaii since 1880. Some people were even astonished that its biological control was successful there, while being ineffective elsewhere. In a recent flora of the archipelago, WAGENER & al. (1990) clarified this point in pointing out that the *Eupatorium odoratum* of the Hawaiian authors was in fact *Ageratina adenophora* (Spreng) R. King & H. Robinson (= *Eupatorium adenophorum* Spreng.), and that *Chromolaena odorata* doesn't yet exist in Hawaii.

Causes of the introductions

If one considers the first apparition of the species in the different zones from which it later spread, it is interesting to point out that for Asia, it was probably introduced for horticultural reasons. In his book on the plants cultivated in the gardens of Calcutta, VOIGT (1845) mentions the species as a plant that could be cultivated in the area. His advice seems to have been followed, since the three first specimens collected 30 years later were all located in the surroundings of the botanical gardens of Dacca, Java and Peradeniya (Sri Lanka). We have seen before that apparently the plant could only manage to escape from the first locality.

A publication from the beginning of the century (B., 1905) mentions the species as being often used in garden cultivation and appreciated for its winter flowers. Besides, in the West Indies, its local name is "Christmas Bush" (CHEESMAN, 1940) in Trinidad and "Fleurit-Noël" in the French speaking islands (DUSS, 1897).

Although its flowering season is moved six months in the southern hemisphere, it might also be for horticultural reasons that *Chromolaena odorata* was introduced in Natal, according to HENDERSON & ANDERSON (1966). Another point of view is related by LIGGIT (1983), referring

to an unpublished document mentioning that the species had arrived in seed-contaminated packing materials unloaded in Durban harbor during the Second World War, which could also have been the case for Mauritius.

Concerning West Africa, as mentioned before, the apparition of the plant in Nigeria can probably be attributed to seeds that arrived along with those of *Gmelina arborea* (IVENS, 1974). If this introduction was casual, on the other hand it is almost certain that the *Chromolaena odorata* has been deliberately introduced to Ivory Coast, following the advice of CHEVALIER (1952). In both cases, the species probably came from Asia and not directly from its continent of origin. This hypothesis is supported by the work of EDWARDS (1974) who studied the germination responses of seeds of *Chromolaena odorata* of various origins.

These examples show the important part intentional introductions of *Chromolaena odorata* have played in the history of its distribution. In Asia, Ivory Coast and maybe Natal, a species now considered as a calamity by most of its people, was introduced deliberately.

Its cultivation for horticultural purposes can be easily controlled in the temperate zone, its survival being subjected to the good will of a gardener who would harbor the plants in his greenhouse during the frosts. It is not the case by far in the intertropical zone. In a probably autogamous species that also reproduces itself by apomictic means (MATHEW & MATHEW, 1983), a single seed can be at the origin of the spread over a whole continent.

Concerning Ivory Coast, it is curious to remark that the great French botanist Auguste Chevalier has taken the responsibility to recommend its introduction in 1952, considering that he was aware of the responsibility of man in the long-distance dispersal of plants (CHEVALIER, 1931) and that he had regarded *Chromolaena odorata* as a "mauvaise herbe" (CHEVALIER, 1949). VAYSSIERE (1957) has later exposed the reasons why he was opposed to this introduction, but at that time, *Chromolaena odorata* was already spreading.

It is maybe too early to judge if this introduction was desirable, especially now that the vegetation in the forest zones of Africa is undergoing great changes. In further articles, I will try to give a few elements to help answer this question, and it could be that the idea of Chevalier was not so bad as it may seem at first sight.

Regions that might still be invaded

Looking at the latest distribution maps, it is obvious that all the regions suitable for *Chromolaena odorata* are not yet invaded, particularly in Africa and in the Pacific Islands. In order to know what regions might still be invaded, it could be interesting to try to predict what would be its potential distribution on a world-wide basis.

At this scale, I will only take into account the climatic factors, comparing the present distribution of the species with a climatic map of the world. All the climate types under which the species has been recorded will be considered as suitable for it. The potential area of *Chromolaena odorata* will then be the whole area covered by these climate types in the world.

For this study, the choice of the climatic map is of course of great importance. The cartographer chooses to place a limit to separate two climate types between which there is, most of the time, nothing else than a gradual variation of the climatic factors. We thus have to choose a map on which these artificial limits fits the best the distribution of our species in the New World, or in Old World regions where the species has been present for a long time and has met its ecological borders.

In this respect, I decided to choose the map "Seasonal Climates of the Earth" by TROLL & PAFFEN (1965).

Referring to this document, one notices that *Chromolaena odorata* can be chiefly found in climates 1, 2 and 3 of the tropical zone (V). It is also found in climates 7 and 4 of the warm-temperate subtropical zone (IV), near the sea or in the vicinity of a climate of the tropical zone (V). Besides, from our data, the species has never been found further than 32° of latitude, nor higher than 2800 m above sea level.

The potential distribution map is presented in fig. 10 and can be compared with the present distribution (fig. 9).

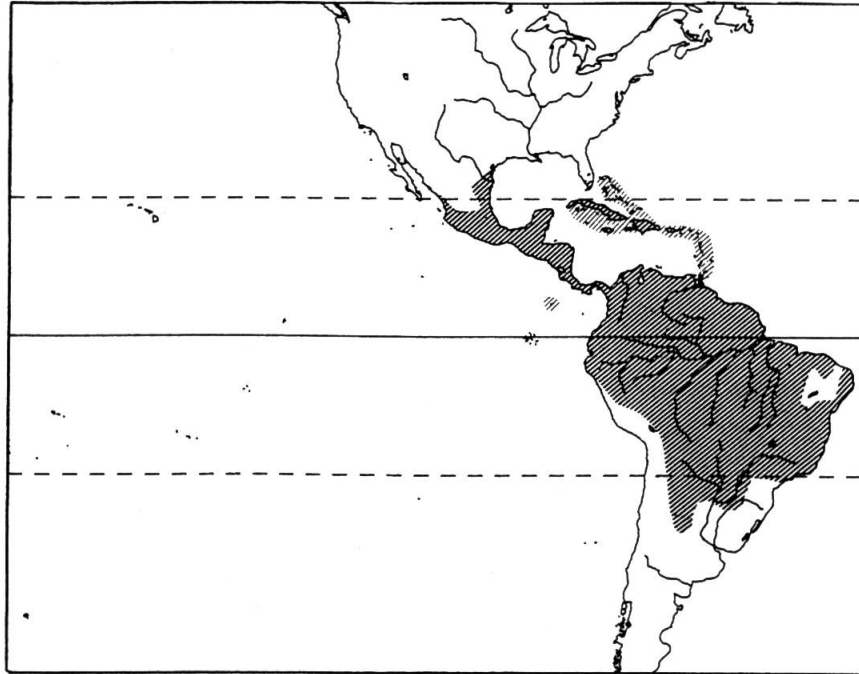
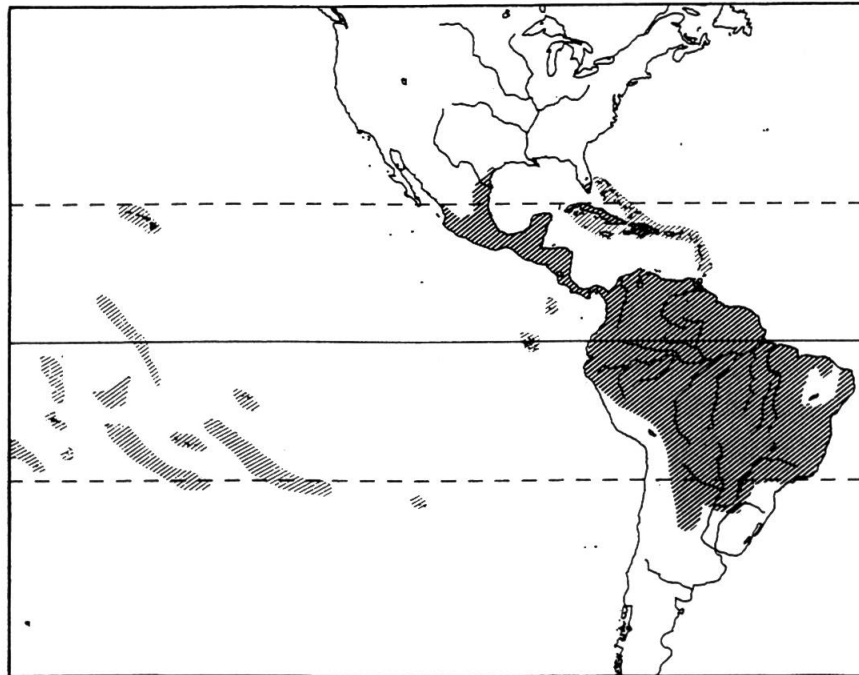
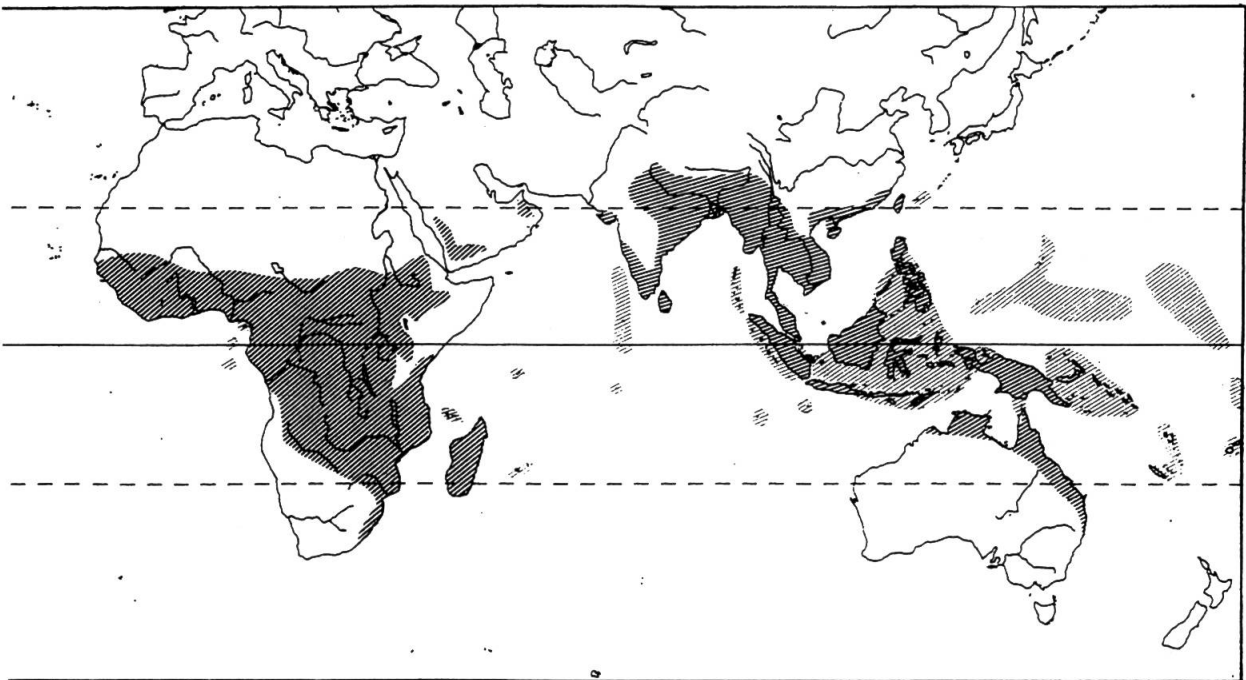
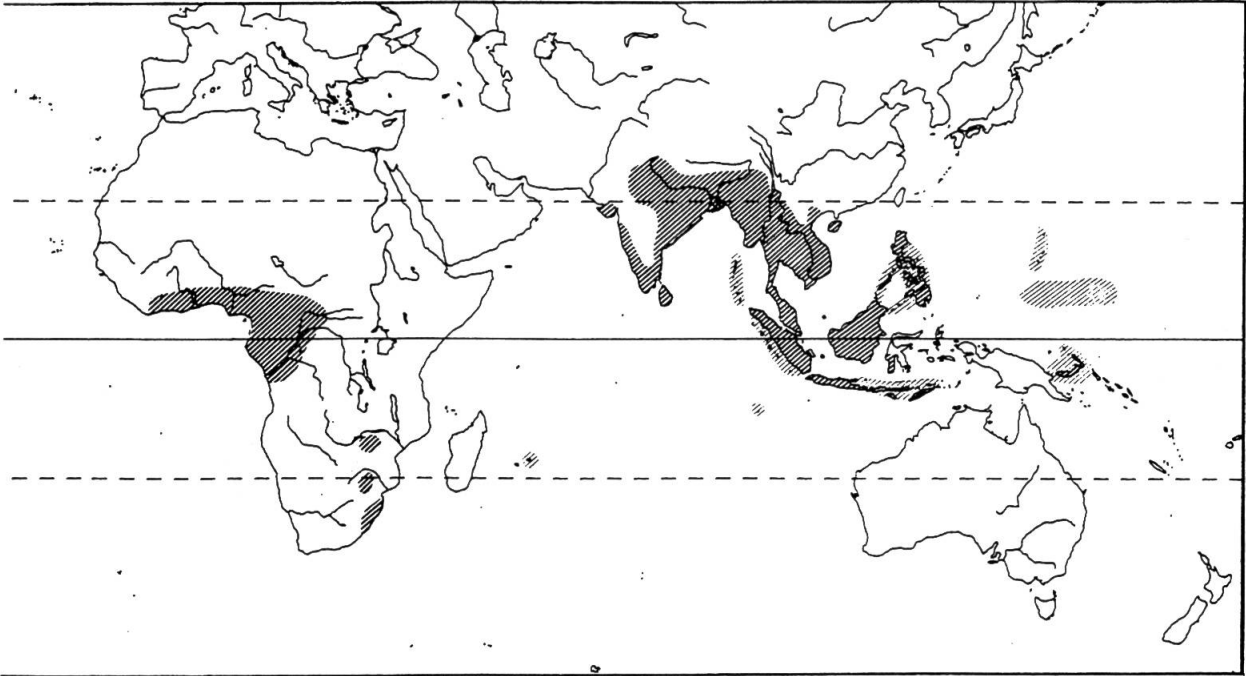


Fig. 9. — Present distribution of *Chromolaena odorata*.

Fig. 10. — Potential distribution of *Chromolaena odorata*.





The regions that are most under threat of invasion are the ones that are not separated from the presently invaded areas by an ecological barrier, be it the sea, a broad mountain range, or an area of unsuitable climate.

In this respect, I would first point out the regions of Africa that are still not invaded, according to my data. The countries concerned are the following:

- | | |
|--------------------------|--------------------------|
| West Africa: | — Sierra Leone |
| | — Guinea-Bissau |
| | — Gambia |
| | — southern Senegal |
| | — southern Mali |
| | — southern Burkina Faso |
| East and Central Africa: | — southern Sudan |
| | — Ethiopia |
| | — Kenya |
| | — Tanzania |
| | — Uganda |
| | — Rwanda |
| | — Burundi |
| Southern africa: | — Angola |
| | — Zambia |
| | — Malawi |
| | — Mozambique |
| | — north-eastern Botswana |

In India and South-East Asia, it seems that the plant, which has been present for a longer time, has little opportunity to extend its range, with the possible exception of the People's Republic of China and Taiwan.

With the help of an anthropochorous long-distance dispersal, a great number of regions are still threatened:

- | | |
|-----------------|---|
| Atlantic Ocean: | — Fernando Po |
| | — Sao Tomé |
| | — Annobon |
| Arabia: | — eastern side of Asir |
| | — region of Masquat |
| Indian Ocean: | — Comoro Islands |
| | — Madagascar |
| | — Réunion Island |
| | — all the remaining islands of the Indian Ocean, with the exception of Socotra. |
| Pacific Ocean: | — all the islands included in the pentagon: Taiïwan-Hawaiï-Galapagos-Eastern Islands-New Caledonia. |
| Oceania: | — not yet invaded islands of Indonesia |
| | — Australia |

Concerning this last country, CRUTWEL MACFAYDEN (1989) has published a map of the threatened regions. We agree mostly with her conclusions (surroundings of Darwin, northern Queensland, and a few points along the eastern coast south to Brisbane), although they might be slightly underestimated. The author considers only the area with rainfall exceeding 1200 mm. From my data, it appears that *Chromolaena odorata* can establish itself in much drier regions. To my

opinion, the whole Arnhem Land is threatened, as well as the entire Cape York peninsula and an uninterrupted fringe along the east coast from there to the latitude of Newcastle or even Sydney, in comparison to what happened in South Africa.

New-Zealand is probably located too much in the south to be threatened.

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